On the Iron Flame Spectrum and those of Sun-spots and Lower-type Stars.

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In 1897 I announced to the Royal Society* that the lines in the spectra of the metallic elements might be separated into two series, one seen best and sometimes alone in the hotter stars, and when higher temperature and electric energy were employed, these I termed "enhanced lines"; the other set, not visible in the hotter stars, but in stars of the solar type, and seen best with lower degrees of heat and electric energy in the laboratory, were referred to as "arc lines."

In a previous paper, published in 1904,† I pointed out that the similarity of spot spectra and that of Arcturus depended upon the equality in temperature of the vapours existing in these celestial light sources. At this time it was held by Prof. Hale and his colleagues, who had studied and published‡ in detail the lines in the spectra of lower-type stars, that the occurrence of spot lines in these spectra indicated the presence on such stars of many spots like those on the sun. In a later publication, however, they state§ that their recent work has led them to the opinion that the comparatively low temperature of these stars offers the simplest explanation of the observations.

It followed naturally that the enhanced lines, representing a higher degree of temperature, or greater electrical excitement, which I showed‖ exist almost alone in some of the high temperature stars, such as α Cygni, should, in the spectra of sun-spots and lower-type stars, be weakened. That this is so has been noted by Fowler¶ and by Mitchell.**

It seemed important to consider as a third term the spectrum given by the comparatively low temperature of the oxy-hydrogen flame and see how the lines in this spectrum behave in the spectra of sun-spots and lower-type stars.

In connection with some researches on meteorite spectra in 1887, many

* 'Roy. Soc. Proc.,' 1897, vol. 60, p. 475.

† 'Roy. Soc. Proc.,' 1904, vol. 74, p. 53.

‡ 'The Spectra of Stars of Secchi's Fourth Type' (The Decennial Publications, Chicago University, 1903).

§ 'Ast. Phys. Journ.,' 1906, vol. 24, p. 185.

‖ 'Roy. Soc. Proc.,' 1899, vol. 64, p. 322.

¶ 'Monthly Notices,' 1906, vol. 61, p. 361.

** 'Ast. Phys. Journ.,' 1906 ,vol. 24, p. 83.

photographs of oxy-coal-gas flame spectra—iron amongst the number—were taken with low dispersion. I gave a short list of lines in the flame spectrum of iron in a paper* submitted to the Royal Society in that year. The wave-lengths of these lines were necessarily given only approximately, so for this present enquiry it has been considered necessary to obtain the oxy-hydrogen spectrum of iron with much greater dispersion and showing more detail. The 3-inch Cooke spectrograph has been used for this purpose, the source of heat being an oxy-hydrogen blow-pipe flame. This spectrum, the lines of which are in course of tabulation, shows many lines which do not appear to have been previously recorded in the flame spectrum. Hartley in 1894 published a record of the lines† occurring in the oxy-hydrogen flame spectrum of iron. A comparison of his record with that obtained from the Kensington photograph shows that many lines occurring in the latter were not recorded by Hartley, and there are numerous discrepancies in wave-length between the two sets. This is probably due to the fact that much less dispersion was used by Hartley.

It is found that the iron flame lines which occur in the region covered by Hale's sun-spot maps are, in general, similarly affected. They show extensive winging in the spot spectrum rather than an increase in the intensity of the line in passing from Fraunhoferic to sun-spot spectrum. It has been noted by Adams,‡ in connection with his work on the spectra of the electric arc core and flame, that the lines relatively much stronger in the flame of the arc are those most affected in sun-spots. The majority of these pronounced "flame of arc" lines exist in the oxy-hydrogen flame spectrum.

By the kindness of Dr. Glazebrook, Director of the National Physical Laboratory, I was enabled to arrange for Dr. H. A. Harker and Mr. C. P. Butler to take several photographs of the furnace spectrum of iron. For this they used one of the large electric resistance-tube furnaces which have recently been installed at the Laboratory. On comparing these with the oxy-hydrogen flame spectrum, it is found that the lines which exist at the lowest temperature of the furnace are just those which occur in the oxy-hydrogen flame. At the higher temperatures employed in the furnace, in addition to the lines just referred to, some of the lines seen in the arc appear; but here again the flame lines are relatively strong as compared with the other lines.

The behaviour of these lines in passing from the solar spectrum to that of Arcturus and α Orionis has been studied. This, however, cannot be done in

* 'Roy. Soc. Proc.,' 1887, vol. 43, p. 120.
† 'Phil. Trans.,' 1894, vol. 185, p. 199.
‡ 'Ast. Phys. Journ.,' 1909, vol. 30, p. 112.

the same detail as in sun-spots, on account of the very much smaller dispersion of the stellar photographs, and consequent bunching of groups of lines of which the individual components can easily be seen in the case of spot spectra. In the more refrangible part of the spectrum, roughly from λλ 4330 to 4000, the flame lines appear to be mainly unaffected in passing from the solar spectrum to that of Arcturus. In the α Orionis spectrum in the same region there is too much absorption to make a satisfactory comparison. In the region from λλ 4330 to 4500 the evidence tends to show that most of the lines are strengthened both in Arcturus and α Orionis. Owing to the difficulty previously referred to of separating the flame lines in stellar spectra from neighbouring lines possibly due to other elements, the strengthening of the flame lines in these stellar spectra cannot be definitely established until stellar photographs of much greater dispersion are available.

The reduction of the lines in the flame spectrum and the comparison of the lines in the laboratory and stellar photographs has been done by Mr. F. E. Baxandall. The photograph of the flame spectrum used in this enquiry was taken by Mr. W. E. Rolston. I have already referred to Mr. Butler's part in the work.